

IN THE ABSTRACT OF THE DISCLOSURE:

Please amend the abstract as follows:

ABSTRACT OF DISCLOSURE

~~Between respective~~ For each of the injection holes 107 on the face of a plate member 111 which is disposed in a fuel passage, grooves 201 are provided which run along the circumferential direction of the respective injection holes 107, and at the positions of the grooves 201, fuel overflows 502 are formed, ~~and further.~~ As a result, contracted fuel flow portions 602 are formed in the injection holes 107, ~~thus,~~ so that the maximum flow velocity of fuel is increased at the injection hole outlet portions, ~~thereby,~~ Thus, a fuel injection valve ~~and for~~ an internal combustion engine ~~of is provided, in which the~~ atomization performance near the injection holes is effectively enhanced ~~are provided.~~

IN THE CLAIMS:

Please amend claims 1-7 as follows:

1. (currently amended) A fuel injection valve comprising, a member having an injection hole, a valve seat located at the upstream side of the injection hole in the direction of fuel flow, a valve body which ~~performs~~ is movable to effect opening and closing of a fuel passage in connection with the valve seat, and a driving means for driving the valve body, wherein ~~either~~ at least one of a groove ~~or~~ and a projecting portion is provided around the injection hole along the circumferential direction thereof.

2. (currently amended) A fuel injection valve comprising, a plate member having a plurality of injection holes penetrating ~~into the plate member in the~~ thickness direction thereof, a valve seat located at ~~the~~ an upstream side of the ~~injection hole~~ plate member in the direction of fuel flow, a valve body which ~~performs~~ is movable to effect opening and closing of a fuel passage in connection with the valve seat, and a driving means for driving the valve body, wherein a flat portion is provided between the respective injection ~~hole~~ holes on the face of the plate member in the fuel passage, ~~is provided~~ as well as a groove formed along the circumferential direction ~~of~~ around the respective injection holes ~~is provided~~.

3. (currently amended) A fuel injection valve according to claim 2, wherein the ~~injection hole is provided in plural number on~~ of injection holes in the plate member ~~while being~~ are separated by the flat portion, and the distance between the groove formed around ~~the~~ an injection hole and the injection hole is ~~determined~~ smaller than the length of the flat portion formed between the injection holes.

4. (currently amended) A fuel injection valve according to claim 2, wherein the ~~injection hole is provided in plural number on~~ of injection holes in the plate member ~~while being~~ are separated by the flat portion, and the grooves provided ~~between in connection with~~ the respective injection holes on the face of the plate member ~~are worked to form in~~ have a circular shape.

5. (currently amended) A fuel injection valve according to claim 2, wherein the ~~injection hole is provided in plural number on~~ of injection holes in the plate member ~~while being~~ are separated by the flat portion, and the grooves provided ~~between in connection with~~ the respective injection holes on the face of the plate member ~~are worked in~~ have a shape such a manner that, the as seen in vertical cross section, ~~of the grooves forms~~ form a V-shape.

6. (currently amended) A fuel injection valve according to claim 5, wherein an inclination angle of the inner wall near each injection hole of the V-shaped grooves provided ~~between in connection with~~ the respective injection holes on the face of the plate member is ~~worked be~~ large in comparison with ~~an~~ the inclination angle of the inner wall thereof remote from the injection hole.

7. (currently amended) An internal combustion engine comprising, a cylinder, a piston which reciprocates in the cylinder, an air intake means which introduces air into the cylinder, an exhaust means which exhausts combustion gas from the cylinder, a fuel injection valve which directly injects fuel ~~in to~~ into the cylinder, a fuel supply means which supplies ~~the~~ fuel from a fuel tank to the fuel injection valve, and an ignition device which ignites a mixture gas of the air introduced by the intake means ~~in to~~ into the cylinder and the fuel injected by the fuel

injection valve ~~in to~~ into the cylinder, wherein the fuel injection valve ~~including~~, has a plate member having a plurality of injection holes penetrating ~~into the plate member~~ in the thickness direction thereof, a valve seat located at the upstream side of the injection hole in the direction of fuel flow, a valve body which ~~performs~~ is movable to effect opening and closing of a fuel passage in connection with the valve seat, and a driving means for driving the valve body, wherein a flat portion is provided between the respective injection ~~hole~~ holes on the face of the plate member in the fuel passage, ~~is provided~~ as well as a groove formed along the circumferential direction ~~of around~~ the respective injection holes ~~is provided~~.

REMARKS

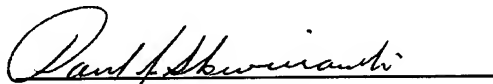
The specification has been amended to correct errors of a typographical and grammatical nature. Due to the large number of corrections thereto, applicants submit herewith a Substitute Specification, along with a marked-up copy of the original specification for the Examiner's convenience. Applicants submit that the substitute specification includes no new matter. Therefore, entry of the Substitute Specification is respectfully requested.

The abstract has been amended to correct errors of a grammatical nature, and the claims have been amended to more clearly describe the features of the present invention.

Entry of the preliminary amendments and examination of the application is respectfully requested.

To the extent necessary, applicant's petition for an extension of time under 37 CFR 1.136. Please charge any shortage in the fees due in connection with the filing of this paper, including extension of time fees, to Deposit Account No. 01-2135 (503.42954X00) and please credit any excess fees to such deposit account.

Respectfully submitted,



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TITLE OF THE INVENTION

Fuel Injection Valve and Internal Combustion Engine Mounting the Same



53.42954X00
Due 7/31/03 GEM
w/decl + assign

5 BACKGROUND OF THE INVENTION

The present invention relates to a fuel injection valve which injects fuel into an internal combustion engine; and ^{more particularly,} ~~the invention relates~~ ^{technique} ~~concerns~~ ^a ~~to a technology~~ ^{that has} for forming fuel spray, excellent ~~in its~~ atomization.

10 ~~CONVENTIONAL ART~~

^{thead} JP-A-10-43640 (1998), in particular page 2 and Figs.1 and ^{example a} 2, discloses one of conventional fuel injection ^{valves} valves in which a valve body ^{is} ~~being~~ provided with a valve seat at an inner wall face forming a fluid passage, a valve member for opening and closing the fluid passage by ^{displacing} ~~being unseated~~ a contacting portion thereof ^{away} from the valve seat and ^{biasing the contact portion thereof into contact with} ~~by being seated the same on~~ the valve seat ^{respectively} and an orifice plate attached to the valve body at the fluid downstream side from the valve member and having an orifice penetrating the orifice plate in its thickness direction, wherein ^{The} ~~the opposing~~ face of the orifice plate ^{which faces} ~~to~~ the valve member, the ~~top~~ end face of the valve member and the inner wall ~~face~~ of the valve body form a substantially disk shaped fluid chamber ~~and~~ in which an obstacle is provided for disturbing the fluid flowing from an opening ^{that is formed} between the contacting portion and the valve seat, to the orifice.

The above ^{referenced} patent document discloses, as the obstacle ^{for} ~~of~~ disturbing the fluid flow ^{the} ~~a~~ provision of ^{an} unevenness which is

provided either on the ~~top~~ end face of the valve member at the fluid flow downstream side from the opening portion between the contacting portion and the valve seat, or on the face of the orifice plate opposing ~~to~~ the valve member.

5 In the above ~~conventional art~~ ^{- described device}, before the fuel reaches to the injection hole, ^a ~~the~~ disturbance is caused ^{in the fuel flow} to make ~~small~~ ^{become small} the particle diameter of the spray. However, in order to reduce fuel consumption effectively, or to reduce ^{the} exhaust amount of unburned gas components (HC, CO) of the fuel, further atomization
10 of the spray is required.

SUMMARY OF THE INVENTION

An object of the present invention is to provide a fuel injection valve, which ^{provides} ~~permits~~ an improvement in atomization performance, and to provide an internal combustion engine which
15 realizes reduction in the fuel consumption amount and reduction in the exhaust amount of unburned gas components (HC, CO) of the fuel with ^{used} the atomization improved fuel spray.

In order to achieve the ^{foregoing} ~~above~~ object, the present invention ^{adopts a configuration in which} ~~introduces~~ a variety of grooves ^{are provided}, including an annular groove ^{surrounding} an injection hole, ^{whereby} ~~thereby~~ through ^a flow contracting effect on the fuel flow ^{which overflows} ~~overflowed~~ the groove in the injection hole, the velocity of the injection flow is increased and the atomization performance is enhanced.

BRIEF DESCRIPTION OF THE DRAWINGS

25 Fig.1 is a vertical cross sectional view of a fuel injection valve representing an embodiment of the present invention;

Fig.2 is a vertical cross sectional view of a nozzle portion in an embodiment ^{of a} ~~according to the~~ fuel injection valve ^{according to} ~~of~~ the present invention;

Fig.3 is a plane view of a plate member ^{as} seen from an injection hole inlet side in the embodiment ^{of} ~~according to the~~ fuel injection valve ^{according to} ~~of~~ the present invention;

Fig.4 is a plane view of a plate member ^{as} seen from an injection valve inlet hole in a modified embodiment ^{of} ~~according to the~~ fuel injection valve ^{according to} ~~of~~ the present invention;

Fig.5 is a ^{diagram} ~~view~~ illustrating ^{the} ~~a~~ manner ^{in which} ~~of an~~ overflow ^{occurs} around an annular groove provided near the injection hole inlet portion in the embodiment ^{of} ~~according to the~~ fuel injection valve ^{according to} ~~of~~ the present invention;

Fig.6 is a ^{diagram} ~~view~~ illustrating ^{the} ~~a~~ manner ^{in which} ~~of~~ velocity acceleration ^{occurs} due to the overflow and atomization promotion due to ^{an} eddy current ^{accordance with} in the present invention;

Fig.7 is a ^{diagram} ~~view~~ illustrating ~~a~~ flow velocity distribution at the injection hole outlet portion in the embodiment ^{of} ~~according to the~~ fuel injection valve ^{according to} ~~of~~ the present invention;

Figs.8(A) through 8(D) are ^{diagrams} ~~views~~ of a variety of groove configurations ^{for use} in the embodiments ^{of} ~~according to the~~ fuel injection valve ^{according to} ~~of~~ the present invention;

Fig.9 is a vertical cross sectional view of a nozzle portion of an embodiment ^{of a fuel injection valve} in which ^{the} ~~upstream~~ ^{side} of the plate member is structured into a radial flow type, according to ~~the fuel injection valve of~~ the present invention;

Fig.10 is a vertical cross sectional view of a nozzle

portion of an embodiment, ^{of a fuel injection valve} ⁴ ~~the~~ ^{side} upstream of the plate member is structured into a collision flow type, according to ~~the fuel injection valve~~ of the present invention;

Fig.11 is a vertical cross sectional view of a nozzle portion of an embodiment, ^{of a fuel injection valve} ^{the} ^{side} upstream of the plate member is structured into a flat valve type, according to ~~the fuel injection valve~~ of the present invention;

Fig.12 is a partial cross sectional view of an embodiment in which a fuel injection valve of the present invention is mounted on an internal combustion engine;

Fig.13 is a vertical cross sectional view of a nozzle portion in an embodiment of a fuel injection valve with a single injection hole according to the present invention; and //

Fig.14 is a partial cross sectional view of an embodiment in which a direct injection type fuel injection valve according to the present invention is mounted on an internal combustion engine.

DETAILED DESCRIPTION OF THE EMBODIMENTS

^{Various} ~~Hereinbelow~~ preferred embodiments of the present invention will be explained with reference to Fig.1 through Fig.14. In the following explanation, a plane ^{which includes} ~~including~~ an axial line of a valve body and ^{which is disposed} ~~in~~ parallel therewith, is called ^a ~~as a~~ vertical cross sectional plane.

Fig.1 is a vertical cross sectional view showing structure of a normally closed ~~and~~ solenoid type fuel injection valve, ^{which is the known} one of fuel injection valve types, representing an embodiment of the present invention. ^{However, it should be understood that the} ~~Although~~ advantages of the

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invention
present ~~embodiment~~ are not limited to application of the invention to a the solenoid type fuel injection valve.

The fuel injection valve, as shown in Fig. 1, is provided with a yoke ^{formed} 105 of a magnetic substance, surrounding a solenoid coil 109; a core 106, which ^{is located} ~~is located~~ at the center of the solenoid coil 109 and one ^{part} ~~end~~ of which is ^{in contact with} ~~contacted to~~ the core 106; a valve body 102, which is lifted by a predetermined amount when the solenoid coil 109 is excited; ^{a valve assembly 103 Davy} a seat face 110 facing the valve body 102; a fuel injection chamber 101, which ^{from} ~~injects~~ fuel ^{that flows} ~~being~~ ^{is injected} ~~flowed~~ through a gap between the valve body 102 and the seat face 110, and a plate member 111 having a plurality of injection holes 107 ^{and which is disposed} under the fuel injection chamber 101.

At the center of the core 106, a spring 108 is provided as an elastic member which works to press the valve body 102 onto the seat face 110. When no current is fed to the coil 109, the valve body 102 is ^{in close contact with the seat face 110} ~~closely contacted~~. Fuel is supplied from a fuel supply port under ^a ~~pressurized~~ state by a fuel pump (not shown). ^A ~~And~~ fuel passage in the fuel injection valve ^{extends} up to the closely contacted position of the seat face 110 with the valve body 102.

When a current is supplied to the coil 109 and the valve body ^{is displaced} ~~displaces~~ 102 due to the magnetic force induced ^{and} ~~and~~ separates from the seat face 110, the fuel is concentrated around the axial center in the fuel injection chamber 101 ^(and) thereafter, the fuel flows along the plate member 111 radially in the outer circumferential direction and is injected through the plurality of fuel injection holes 107 toward ~~such as~~ ^{for example} an intake port of the engine.

Fig.2 is a vertical cross sectional view of the nozzle portion. A feature of the present ^{invention} ~~embodiment~~ is that grooves 201 are formed ^{in the vicinity of} ~~between~~ the respective injection holes 107 on the face of the plate member 111 in the fuel injection passage, ^{they extend} and along the circumferential direction of the respective injection holes 107, as shown in Fig.3. Since the grooves are ^{so as to surround} ~~provided between~~ the respective injection holes 107, the respective grooves are naturally formed near the respective injection holes 107. Further, ~~the~~ grooves ~~201~~ ^{201,} other than the annular grooves, as shown in Fig.3, can be used. For example, Fig.4 shows a modification in which, instead of ~~the~~ continuous annular grooves, four rectangular shaped grooves 401 are provided ^{around} ~~in~~ the circumference of ^{each of} the respective injection holes. Each of the grooves 401 is configured in such a manner that, when ~~assuming~~ ^{the} the length of the rectangular groove 401 in circumferential direction of the injection hole ^{is} ~~as~~ d and the length thereof in radial direction of the injection hole ^{is} ~~as~~ t , ^{the} ~~ratio~~ d/t is selected to be more than 1, ^{so} ~~that~~ $d > t$, ^{the} ~~reason~~ ^{for this} ~~of which~~ is that, in order to induce ^{an} ~~the~~ overflow effect due to the grooves more efficiently, it is preferable that the circumferential length d is longer than the radial direction length t . ^{Therefore} ~~therefore~~, the most preferable configuration is ^{used} ~~the~~ circumferential grooves. Further, in ^{the} Fig.4 modification, although four ~~pieces of~~ rectangular grooves 401 are provided for each of the injection holes, the number thereof is not limited ^{to four, and may be set in consideration of} ~~thereto~~ under the allowable physical space therein.

Still further, as shown in Fig.3, a flat portion (plane

portion) 203 is formed between ~~the~~ adjacent injection holes 107 ~~at the~~ outside of the grooves ²⁰¹ ~~the~~ distance (interval) L between the adjacent injection holes 107 ~~at the~~ outside the grooves 201 on the flat portion 203 is determined ^{to be} longer than ^{the} distance (interval) ^l ~~the~~ between the inner edge of the groove 201 and the outer edge of the injection hole 107. In other words, the groove 201 is disposed close to the injection hole 107 in such a manner that the distance ^l ~~the~~ is shorter than the distance L. Further, the flat portion (plane portion) 203 contributes ^{an enhancing of} to ~~enhance~~ the overflow inducing effect, which will be explained later.

The function and advantages of the present ^{invention} ~~embodiment~~ will be explained with reference to Figs. 5 through 7. Because of the shaping of the grooves, ^{described} ~~as explained~~ above, ~~as shown in~~ Fig. 5, fuel 501, which comes from the outer circumferential direction, flows deep into the groove, forms overflows 502 and flows into the respective injection holes 107 ^{as shown in Fig. 5}. Thereafter, as shown in Fig. 6, because of the effect of the ^{fuel} flows forming the overflows 502, fuel flow 601 ^{takes the form of} ~~forms~~ a contracted flow portion 602 ^{having a} ~~of which~~ diameter ^{which} is slightly smaller than that of the injection hole 107 ^{as the fuel is} ~~and~~ injected from the injection hole 107. Fig. 7 shows a flow velocity distribution at the injection hole outlet portion. As will be seen from Fig. 7, with the provision of the grooves 201, since the overflow 502 and the contracted flow portion 602 are formed, the maximum flow velocity in the flow velocity distribution 702 at the injection hole outlet portion is increased in comparison with that in a flow velocity distribution

701 in the case of no provision of the grooves 201. Because of this acceleration effect, ~~the~~ ^{the} turbulence of ~~the~~ ^{the} gas and ~~the~~ ^{the} liquid interface between ~~the~~ ^{the} fuel and ~~the~~ ^{the} air is enhanced, and ~~a large~~ ^{a large} number of vortexes 603 are formed, which reduces the diameter of spray particles 605.

5 Figs. 8(A) through 8(D) show ~~different cross-sections~~ ^{different cross-sections} configurations of the grooves 201, ~~that are~~ ^{that are} formed around ~~the~~ ^{an} injection hole 107. Fig. 8(A) shows ~~an instance~~ ^{an example} wherein a rectangular groove 201A is formed, Fig. 8B shows another instance wherein a V shaped groove 201B is formed, Fig. 8(C) shows still another instance wherein a groove 201C is ~~formed of which~~ ^{so that the} inner side wall inclination angle near the injection hole is designed ~~to be~~ ^{to be} steeper than that remote from the injection hole, and Fig. 8(D) shows a further instance wherein a groove 201D is formed in which the top level of a projection 204 around the injection hole 107 is formed ~~to be~~ ^{to be} higher by a height H than that of the surface of the plate member 203 at the upstream side of the groove. The groove configurations as shown in Figs. (8A) through 8(D) can basically form the overflows 502. Further, with regard to the grooves as shown in Figs. 8(B) and 8(C), the bottom shape need not be an acute angle, but can be rounded. 20 Still further, with regard to the groove as shown in Fig. 8(D), the height H is ~~preferable to be~~ ^{preferably} smaller than the diameter ϕD of the injection hole 107, ~~so as~~ ^{so as} to form the overflows.

As has been explained above, with the fuel injection valve of the present embodiment, the overflows 502 are formed at ~~the~~ ^a position where the grooves 201 are disposed, and, further, through the formation of the contracted flows 602 in the fuel injection holes 107, the maximum flow velocity at the fuel

injection outlet portion is increased, ^{whereby} ~~thereby~~ the turbulence of the gas and ^{the} liquid interface between ^{the} fuel and ^{the} air is enhanced, and the atomization performance is improved.

5 Figs.9 through 11 show vertical cross sectional views of nozzle portions ~~in~~ ^{of} respective embodiments wherein the structures upstream ^{of} the plate member 111 of the fuel injection valve according to the present invention are formed respectively in a radial ~~flow~~ ^{flow} type, a collision flow type and a flat valve type.

10 In the radial ^{of fuel injection valve,} flow type, as shown in Fig.9, ^{there is} a fuel contraction portion 901, which ~~once~~ contracts the fuel flowing through the gap between the valve body 102 and the seat face 110 ~~is provided.~~ ^{Under} ~~under~~ the fuel contraction portion 901, ^{there is} a fuel outwardly radiating chamber 902, which forces ~~to flow~~ ^{to flow} the fuel,
 15 toward the outer circumference ~~is provided;~~ and, further, under the fuel outwardly radiating chamber 902, a plate member 111 having a plurality of injection holes is provided.

In the collision ^{of fuel injection valve,} flow type, as shown in Fig.10, the fuel ^{flows where} injected outwardly through the respective injection holes 107 on the plate member 111 ^{collide with} ~~is collided~~ each other at a collision point 1001 ^{so as} to divide the spraying direction into two directions.

In the flat valve ^{of fuel injection valve,} type, as shown in Fig.11, instead of the ball valve type, as shown in Fig.2 and 10, the valve body 1101 is formed ^{as} ~~is~~ a flat type, and, further, ^{an annular} ~~a~~ seat face 1102, through
 25 which fuel supply is controlled by the vertical movement of the valve body 1101, is disposed between the valve body 1101 and the plate member 111.

Any ~~types~~ of the above ¹⁰ ~~described fuel injection valves of the~~ radiation flow type, collision flow type and flat valve type ~~fuel injection valves~~ can achieve the same or ^{an even} further atomization performance in comparison with the fuel injection valve ~~as~~ shown in Fig.2.

5 Fig.12 shows an example in which the fuel injection valve 1201 according to the present invention, ~~as shown in Fig.1~~ is mounted on an internal combustion engine. Since ~~as~~ the fuel injection valve ^{corresponds to} a like solenoid type fuel injection valve ^{described with reference} as shown, ^{in the foregoing embodiments} ~~the above embodiment is used,~~ ^{a repeated} explanation of the constitutional elements ^{thereof} is omitted. The internal combustion engine as shown in Fig.12 is constituted by a cylinder head 1202, an intake valve 1203, an ignition plug 1204 which ignites the mixture gas of fuel and air, a piston 1205, a cylinder 1206, an exhaust valve 1207, an intake port 1208 which introduces air in
10 to the cylinder 1206, and an exhaust port 1209 which exhausts the combustion gas from the cylinder. Further, the fuel injection valve is provided with a connector through which ^{an electrical} current for driving the injection valve is supplied.

Further, in Fig.12, the intake valve 1203 is shown in ^a closed state. However, actually, when the fuel is injected in ^a spray from the fuel injection valve 1201 to the combustion chamber 1211, the intake ^{valve} ~~valve~~ 1203 is opened. Herein, the fuel injection start timing of the fuel injection valve 1201 may ^{be} ~~be~~ either when the intake valve is actually opened or before the intake valve 1203 actually starts valve opening in view of the fuel flying time.
25 In such instance, the ^{fuel} flying time is set in such a manner that the fuel injected at the injection start reaches ~~to~~ the intake

valve at the ~~time~~^{time} when the intake valve 1203 is actually opened. Further, within an allowable range, the fuel injection start timing can be set so that the fuel injected at the injection start reaches the intake valve 1203 at the timing before the intake valve 1203 starts actual valve opening.

In the above ~~embodiments~~^{described}, ~~the~~ fuel injection valves ^{are employed} in which a plurality of injection holes 107 are provided on the plate member 111; however, the present invention is not limited to such embodiments, in that, as shown in Fig. 13, for ~~the~~^a fuel injection valve having a single injection hole 107 on the plate member 111, ^{single} a groove which runs along the circumferential direction of the injection hole 107 can be provided.

Fig. 14 ^{is} ~~shows~~ a partial cross sectional view of a further embodiment, in which a direct injection type fuel injection valve 1401 ^{having a} ~~including the~~ single injection hole 107 ⁱⁿ ~~on~~ the plate member 111, ^{in Fig. 13, from which} as shown ~~above~~ and ^{is injected} injecting fuel directly into the combustion chamber 1211, is mounted on the internal combustion engine. The direct injection type fuel injection valve 1401 is ^{mounted} directly on the cylinder 1206 near the intake valve 1203, and ^a fuel spray 1402 is directly injected into the combustion chamber 1211.

In the above ~~embodiments~~^{described}, ~~the~~ solenoid type fuel injection valves have been ^{considered} ~~explained~~, however, the present invention is not limited to ^{the use of valves} such ~~embodiments~~, and the present invention can be generally applied to fuel injection valves other than the solenoid type within ^a ~~the~~ range where ~~the~~ substantially the same function and advantages as the present embodiments can be obtained.

each of 12
According to the above ~~respective~~ ^{- described} embodiments,
^{structure} a ~~measure~~ for atomizing fuel is provided near the injection valve,
^{so that} an effective fuel atomization can be achieved.

^{in an} Therefore, ~~the~~ internal combustion engine according to
5 the ~~present invention, which is~~ ^{present invention, which is} ~~embodiments being~~ provided with the fuel injection valve of
the present invention, since the atomization performance of the
fuel spray injected from the fuel injection valve is excellent,
the exhaust amount of unburned components (HC, CO) can be reduced.

According to the present invention, through the
10 formation of ^{fuel} ~~the~~ overflows at ~~the~~ positions where ~~the~~ grooves
^{in relation to the fuel injection holes} are located, and, further, through the formation of ^a ~~the~~ contracted
^{fuel} flow portion in the injection holes, ^{which provides} ~~and with~~ the advantage of
increasing the maximum flow velocity of the spray at the injection
hole outlet portion, ^{the} turbulence of ^{the} gas and ^{the} liquid interface
15 between ^{the} fuel and ^{the} air is accelerated and the atomization
performance is improved. Thereby, in ^{an} ~~the~~ internal combustion
engine using the same, since the atomization performance of the
fuel spray injected from the fuel injection valve is excellent,
the exhaust amount of unburned components (HC, CO) can be reduced.